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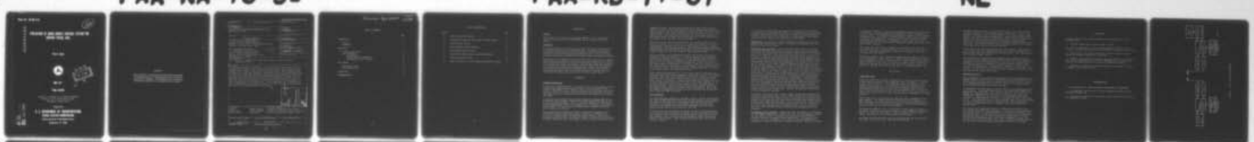

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EVALUATION OF RADIO REMOTE CONTROL SYSTEM FOR AIRPORT VISUAL AIDS

Bret B. Castle

JUNE 1977

FINAL REPORT

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16. Abstract
An evaluation was made to determine if a particular radio remote control system could provide reliable control of distant airport visual aids in place of laying lengthy control cables to the system's power regulators. Simple operation and flexibility of usage were required of the system, as well as continual monitoring of the status of the remote stations, emergency operation during electrical power failures, and reliability of operation approaching hard-wire systems. Results show that during the 5,000 hours of testing the system worked well, except for high and low operating temperature problems caused by the use of unreliable commercial components in the transceiver. It was recommended that following transceiver improvements, operational evaluation in-service type tests be performed on the system in an operating airport environment.

17. Key Words
Airport, Visual Aids, Control Systems, Runway Lighting, Taxiway Lighting, Reliability

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INTRODUCTION

PURPOSE.

The purpose of this effort is to determine whether or not a radio remote control system can provide reliable remote control of visual aids on an airport.

BACKGROUND.

The standard method of controlling visual aids is by way of directly buried or duct-enclosed cable to the power regulators. In addition to expensive construction, this method is also quite inflexible when additional runways and approach lights are required on established airports. Because of these factors, radio control of lights used as airport visual aids has been proposed.

Distances up to 9.3 kilometers (km) (5 nautical miles (nmi)), which is approximately the maximum expanse of an airport, have been covered by use of small radio systems for years, with the major problems being reliability and security of protection from outside interference. Most of these small radio systems have no reporting or monitoring capability, which reduces their reliability. If reliability and security can be demonstrated, a remote control method using radio will permit control of runway and approach lighting aids from the air traffic control tower without use of costly control cables.

DISCUSSION

EQUIPMENT DESCRIPTION.

A contract, No. DOT-FA74WA-3433, was awarded to ASE, Inc., to develop a secure, reliable radio control system and to install it at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey. The system (figure 1) was to be a digital telemetering system for monitoring and controlling visual aids with a high degree of reliability and security in an airport environment.

A transceiver was developed from a modified commercial frequency modulation transceiver (166.175 megahertz (MHz)) with enough transmitting power (6 watts) to cover the required range. The logic circuitry consisted of a double-bit, triple-encoded message (figure 2), transmitted in a half-duplex, time-division, multiplex mode. The power supplies, display panels, antennas, and battery units completed each station.

Message security is provided by a digital processor which generates all of the required timing and sequencing signals. Briefly, a 1.0-MHz crystal oscillator is counted down to provide the required signals. Before every message transmission, this clock supplies a series of signals that synchronizes the remote clocks (bit sync), then sends a 17-bit frame sync before any coded

message is started. The messages are coded in accordance with the switch positions, "double bitted" (formed twice), and then transmitted three times past a voting circuit to assure complete message security. The central station sends messages to each remote station in its own time frame as set up by the central clock. The central station controls all of the remote stations in this manner, while the remote stations can only reply to the central station. The remote stations can never talk to each other.

Reliability of the system is assured by (1) use of highly reliable parts in most of the system, (2) careful use of the individual components to prevent overdriving of the parts, and (3) use of backup systems in case of primary system failure. This includes batteries, with which to pick up the voltage if the powerlines fail, and a memory in the output circuits to insure that no light change or dropout of lights can happen in case of power failure.

After more than a year of design, fabrication, and testing, the system was installed at NAFEC in November 1975. A central master station (figure 3) was placed in building 161 (figure 4), near the airport's primary runway, and two remote stations were installed at strategic positions. One of them, remote No. 1, was located directly down runway 13, 3.7 km (2 nmi) away in the line of sight, in building 226. The other, remote No. 2 (figures 5 and 6), was located 9.3 km (5 nmi) away at the outer marker of runway 13 and hidden by a forest of trees. Four yagi directional antennas were used, one at each remote station, and two at the central station.

Twelve switch positions (figure 7) at the central station controlled lights at each remote station which simulated the controlling of visual aids at remote positions. When a switch was turned ON at the central station, an encoded signal was sent to the called remote station, where it turned ON a light. After receipt of the signal, the remote station sent back an identical signal to the central station and turned ON a light at the central station. If an incorrect signal was received at the central station, the light blinked, indicating a fault. This continuous monitoring signal thereby assured that the signal had been correctly received at the remote station. This system was designed to accommodate 10 remote stations if needed, but only two were used in the model under evaluation.

TEST PROCEDURES.

The field evaluation consisted of two types of tests. One was an operational test which included operating continuously through foliage, around buildings and airplanes, and under various interfering conditions that can happen on an airport. The second was an environmental test that included use of scientific test chambers and specification requirements plus the normal weather problems such as rain, snow, heat, and cold.

In-service tests were planned for the system, but due to the unavailability of the expected test bed of approach lights, only light emitting diodes were used during the tests, with chart recorders attached. Some type of interface (probably a set of relays) would be required to operate a full-scale system of airport lights. Small transistor amplifiers were used to drive the chart recorders.

A test plan was developed that included (1) a 1-month period for debugging the system after it was installed at NAFEC, (2) a 6-month period of continuous operation, during which time a record was to be kept of any discrepancies or troubles that developed in the system, (3) a 1-month period of environmental testing, and (4) a report at the completion of this program.

INSTALLATION. The system was installed at NAFEC on November 13, 1975, and debugging took approximately 1 month. Installation and debugging was accomplished by contractor personnel.

OPERATIONAL TEST CONDITIONS. After satisfactory installation of the three stations, a period of operational testing was started. Each day the system was checked for troubles that could be caused by normal airport interference, such as the operation of F106 and C5A aircraft within 200 feet of the central station. At least once a week interference was artificially caused, such as running an electric drill from the same electrical outlet employed by the radio control system, reasonable pounding on the side of the equipment cabinets, and operating other radio and radar equipments in the immediate area of the central station. Other checks included checking the voting circuit by shorting out one and then two of the three circuits (it should operate with one of three circuits improperly coded, but if two out of three did not receive the proper signals, it should reject the code). Chart recorders were installed across the lights at the central station, and a record was kept of the troubles encountered. A stepping switch was installed in such a manner that each of the 12 switches was operated ON and OFF sequentially at approximate 10-minute intervals throughout the day and night. For approximately 1,200 operating hours the switches were turned ON and OFF in this manner. Following this testing period, the stepping switches were changed, and half of the switches (six) were programmed to be operated manually (turned OFF and ON at the discretion of the operator), while the rest (six) were continually operated every 10 minutes for another period of 2,000 operating hours. Finally, for a period of about 350 hours, two chart recorders were installed, one at the central station and one at remote No. 1 station, and these were synchronized for double checking of problems.

In addition to the above types of tests, signal strength tests were made by rotating the yagi antennas away from the remote stations and by substituting the use of a dipole at the central station. The system was in operation from November 1975 through July 1976, which included blizzard-type weather, conditions when the temperature went down to -15.5° celsius (C) (+4° fahrenheit (F)), to warm weather, when the temperature reached +29° C (+84° F), and included snow, hail, rain, and winds up to 112 km/h (60 knots). In all, a total of more than 5,000 operating hours was recorded on the equipment during this evaluation.

ENVIRONMENTAL TEST CONDITIONS. Remote system No.1 was placed in an environmental test chamber (figure 8), on December 15, 1975, for performance of temperature and humidity tests in accordance with specification FAA-G-2100/1b, entitled "Electronic Equipment, General Requirements." This specification basically calls for the equipment to be soaked at the low temperature for a minimum of 2 hours, at which time it shall be turned ON. Within 15 minutes,

it must operate properly. Then, with the equipment operating, the temperature is increased to the high temperature and maintained at this temperature for at least 6 hours. The equipment being tested must continue to operate properly during this time. In addition, a relative humidity check is made consisting of soaking the equipment (not operating) for at least 24 hours at the high temperature and high humidity. The equipment is then turned ON and must operate properly within 15 minutes and continuously operate properly for 2 days under normal conditions.

This system was tested under environment II conditions of the above specification, which called for a temperature range of -10° C (+14° F) to +50° C (+122° F) and a relative humidity of 5 percent to 90 percent. The results are shown under TEST RESULTS.

During this period of time, oscilloscope photographs were taken at the output of the discriminator of the remote No. 1 system, showing different configurations developed by different switch positions. Figure 2 shows (A) the complete sweep, including the bit sync, frame sync, the central station transmitted pulses; (B) expanded view of the bit and frame sync pulses; (C) output with switch No. 4 ON; and (D) output with switches 2, 4, 6, and brightness 1 ON.

TEST RESULTS

OPERATIONAL TESTS.

During the 9 months of operation (5,000 hours), it was found that the system operated very well as long as the temperature did not go below -5° C (+23° F) or above +38° C (+100° F). This problem was found to be connected to the commercial-type transceiver. No catastrophic component failures occurred during this operating time of 24 hours per day operation, although some discriminator problems occurred during the environmental tests. The security logic of the system worked very well, and there seemed to be no way that the system could be deceived into giving a wrong signal or responding to an outside radiation.

Efforts were made to jam the system by operating another transmitter on the same frequency. The results showed that the system could be jammed, i.e., made inoperative, by overpowering the receiver so that the lights would stay ON as last called for, but efforts were unable, by injecting interference, to make the system turn ON or OFF the wrong lights.

The system was designed so that if the central station failed to operate for any reason, the remote system would remember the last command and continue to operate the lights as last called for, with no change or failure of the lights. This feature of the system worked without failure.

Low signal strength produced by lowered antenna gain made the system continually hunt for a correct code. This was to be expected.

Phenomena commonly referred to as "glitches" occurred on the chart recorder at remote station No. 1 on an average of three times a day. A "glitch" was defined as a momentary loss of synchronization - one or more voltage output signals would reverse themselves momentarily. While these event marks would appear on the chart recorder, no change in the lights could be detected. No pattern to these glitches was apparent during the test period. Remote station No. 2 was not monitored by a chart recorder, and therefore no glitches were noted. This possible problem could be protected against by introducing a time delay in the output of the logic circuitry.

It was required that the system operate for 3 hours without commercial electrical power. This was accomplished by having a battery pick up the load when the commercial power dropped below its usable value. This battery system worked without a single failure.

One consideration of operation was the amount of time required to activate the lights after the appropriate control switch was closed. This system was designed so that if 10 remote stations were used with one central station, and each remote station had a capability of controlling seven groups of lights plus five brightness steps, it would require a maximum of 1.5 seconds to complete the turn-ON cycle. The field evaluation system contained two remote stations, and the time to operate the light cycle was about 1/3 second. This operating time was judged satisfactory.

ENVIRONMENTAL TESTS.

The environmental tests performed during December 1975 in the temperature and humidity chambers indicate that (1) there was no humidity problem and (2) the system would not operate properly at temperatures of lower than -5° C (+23° F) nor at temperatures above +38° C (+100° F). Remote No. 1 had approximately 700 operational hours when these tests were made.

An investigation was then begun to find the cause for the temperature specification failure. Thermocouples were placed on four spots in the system, and temperature checks were made. With the test chamber at +50° C (+122° F), the highest spot temperature was +68° C (+154° F) on the 5-volt power supply. Although this temperature was acceptable for the components in the logic circuitry, it seemed excessive for some of the commercial parts in the transceiver. It was determined that the logic circuitry, which was a modular design for ease of changing, was made up of highly reliable parts, while the commercial grade transceivers were not designed to meet broad temperature specifications.

Following the spot temperature checks, the transceiver was placed in the test chamber and further tests were made. Two capacitors in the discriminator section were found to be problem components. After they were replaced with more reliable parts, the entire system was again subjected to the temperature and humidity tests, and this time it passed the standard series of tests. Further problems developed later in this same discriminator section, and new coils were installed in March 1976. Still, temperature problems remained the major cause of any malfunctions throughout the 9 months of testing.

CONCLUSIONS

From the results of the testing performed in this evaluation, it can be concluded that:

1. The radio remote control system concept is valid.

2. With the installation of more reliable components and minor design changes, the system could approach the reliability of hard-wire control systems.

3. The security of the system (capability to operate properly under all airport environmental conditions) is excellent.

4. Security and reliability are enhanced by system capability to remember the last correct command during any incorrect commanding and to maintain input power by the backup battery system in case of primary power failure.

5. Simplicity of operation is excellent, and the time required to complete a command is well within any need.

RECOMMENDATIONS

It is recommended that, should operational requirements be established:

1. An operational specification be written regarding the concept of this system for possible use.

2. An in-service evaluation be performed at a busy airport after correcting the temperature problem.

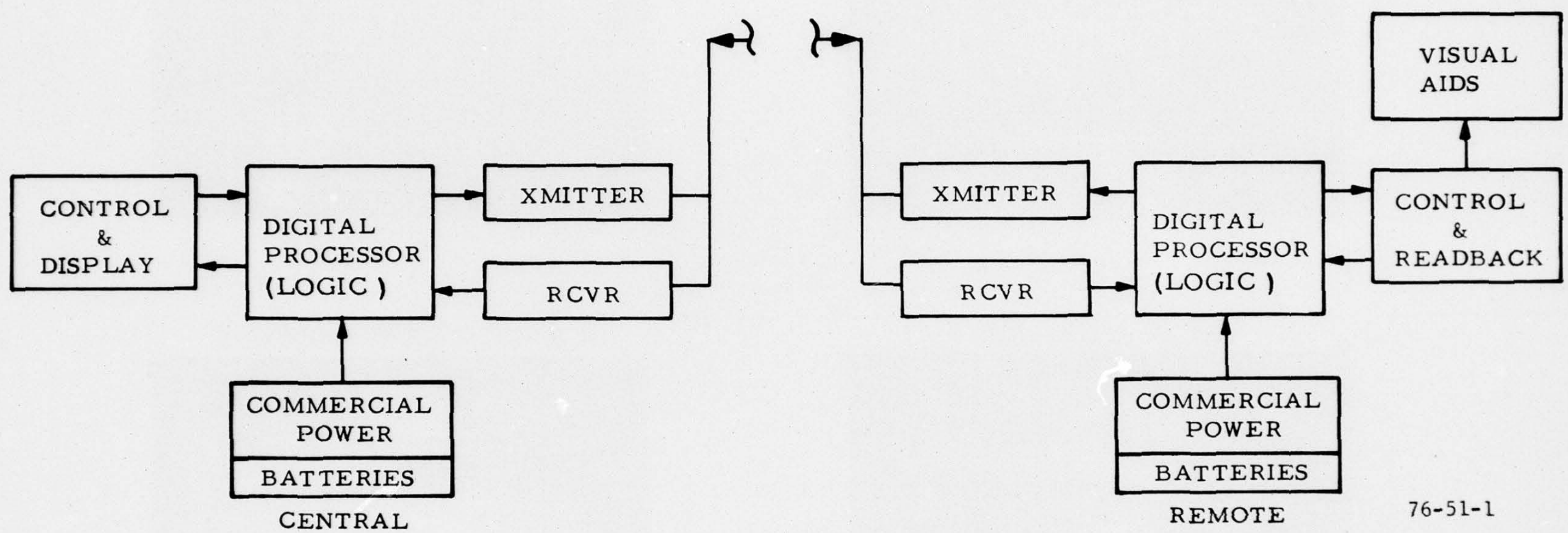
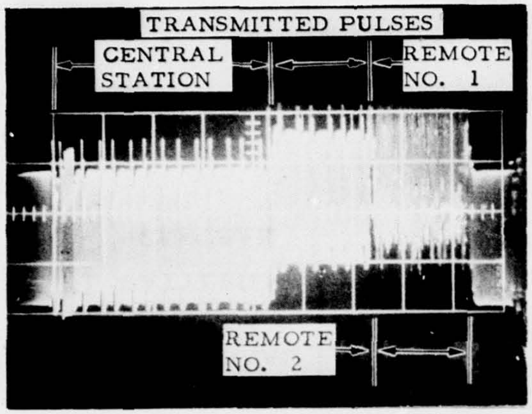
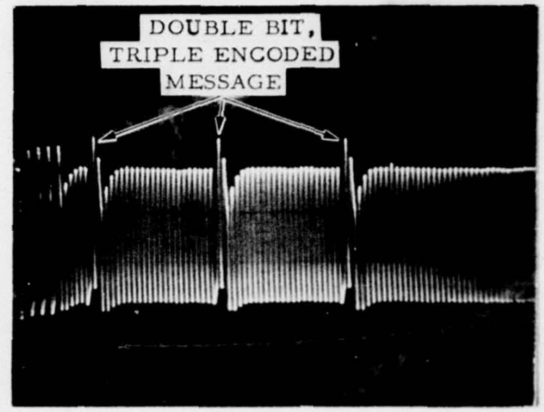


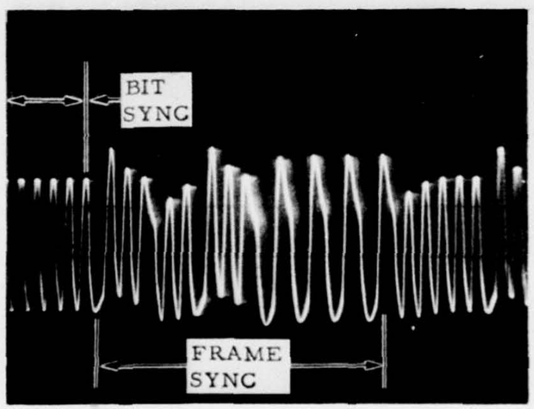
FIGURE 1. BASIC SYSTEM BLOCK DIAGRAM

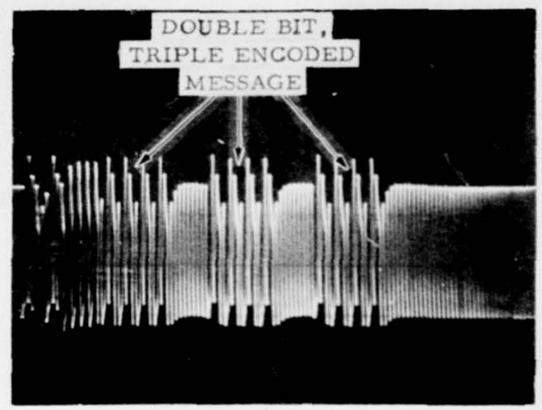


A. COMPLETE SYSTEM SWEEP



C. SWITCH "4" ON





D. SWITCHES "2", "4", "6", AND "BRIGHTNESS 1" ON

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FIGURE 2. OSCILLOSCOPE DISPLAY OF DISCRIMINATOR SIGNAL OUTPUTS

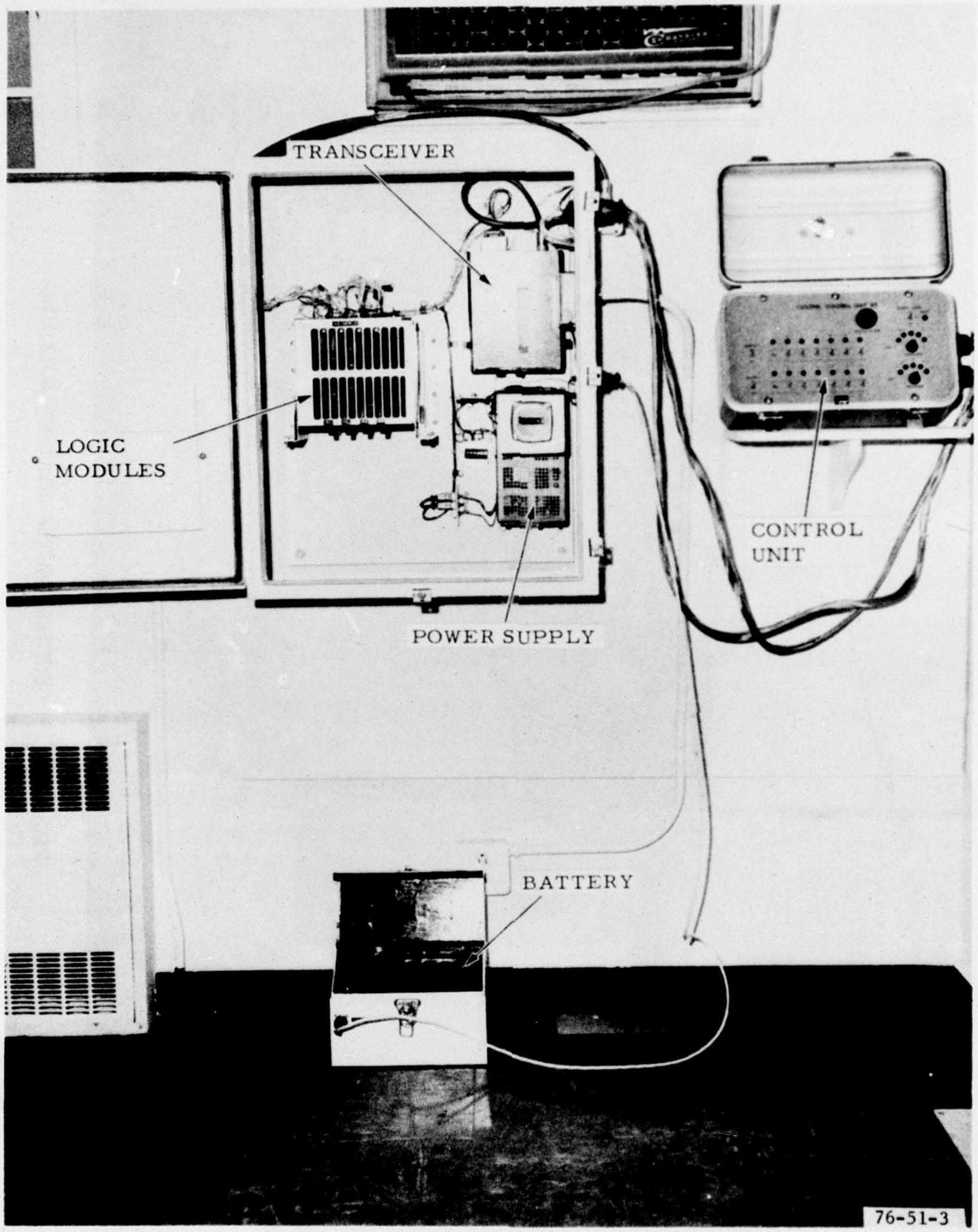

FIGURE 3. CENTRAL MASTER STATION

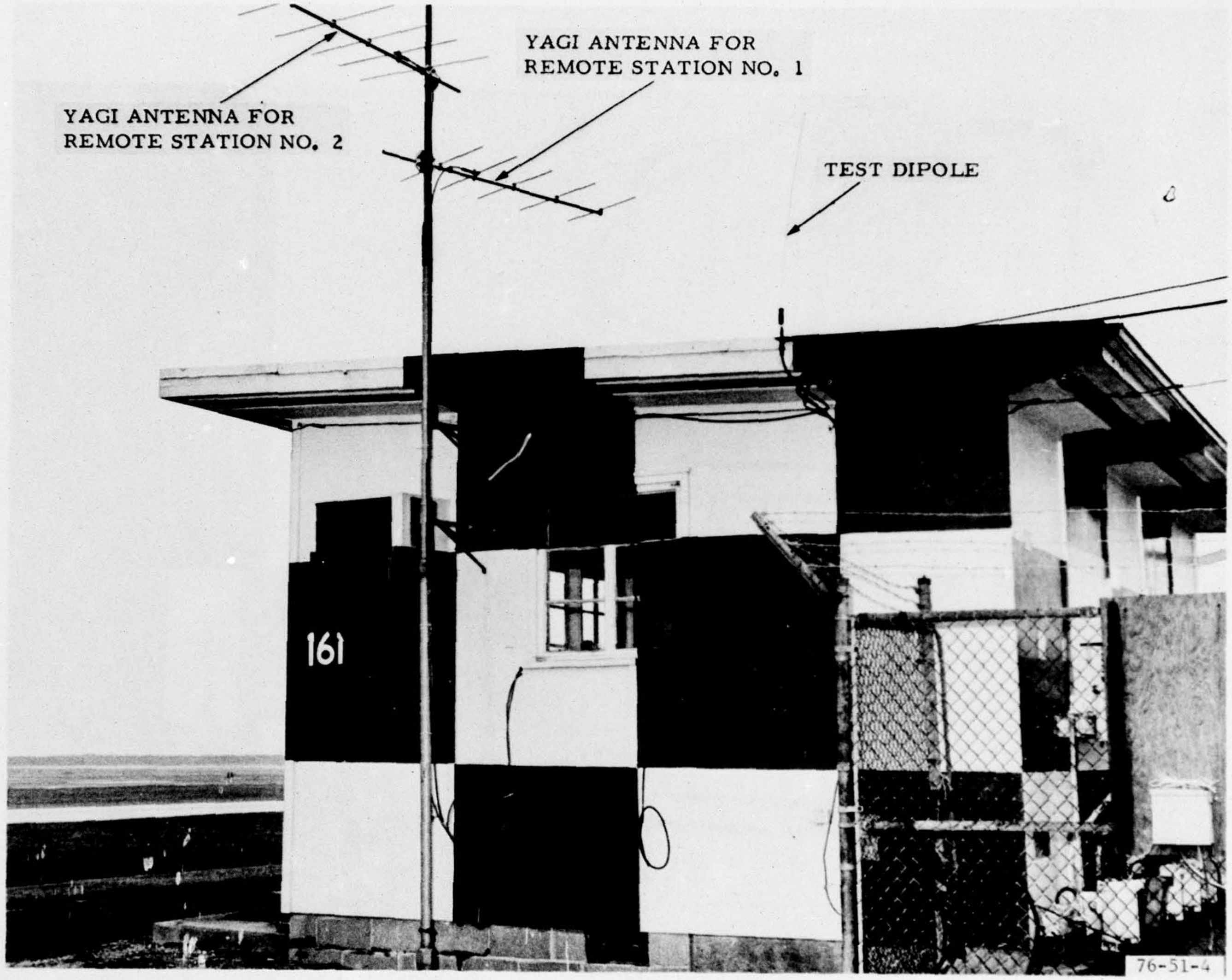

FIGURE 4. CENTRAL MASTER STATION BUILDING

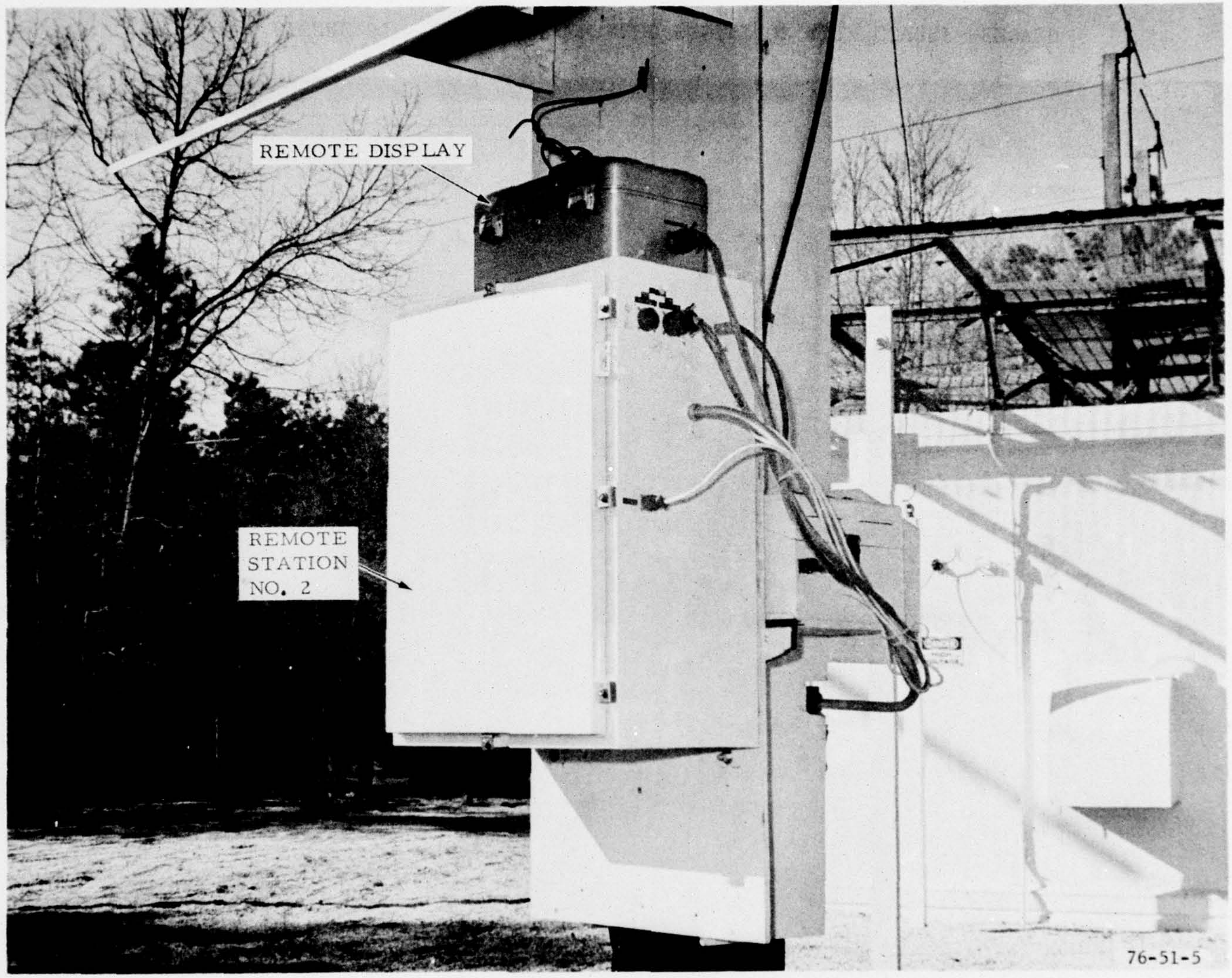

FIGURE 5. OUTER MARKER REMOTE STATION

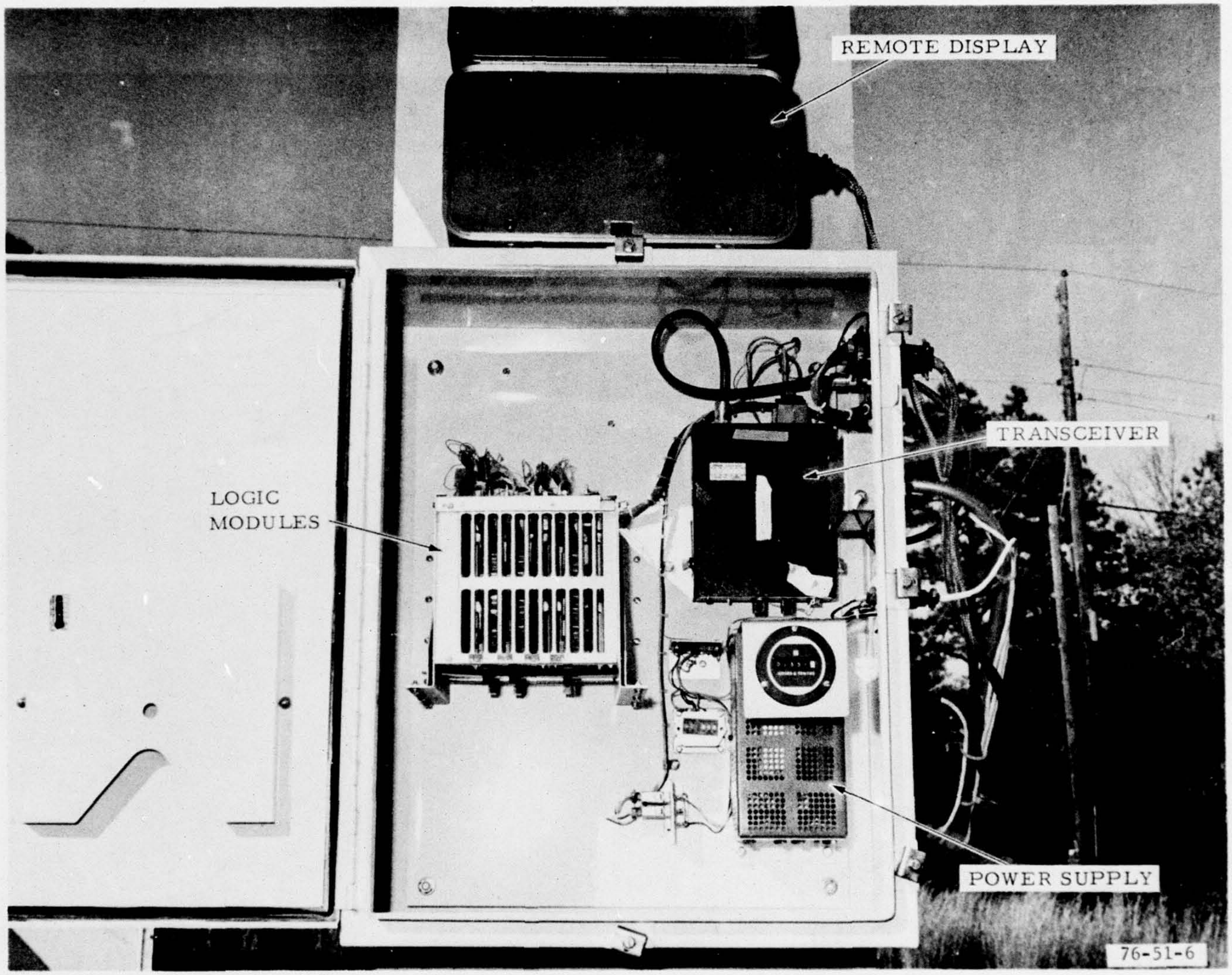

FIGURE 6. OUTER MARKER REMOTE STATION WITH COVERS REMOVED

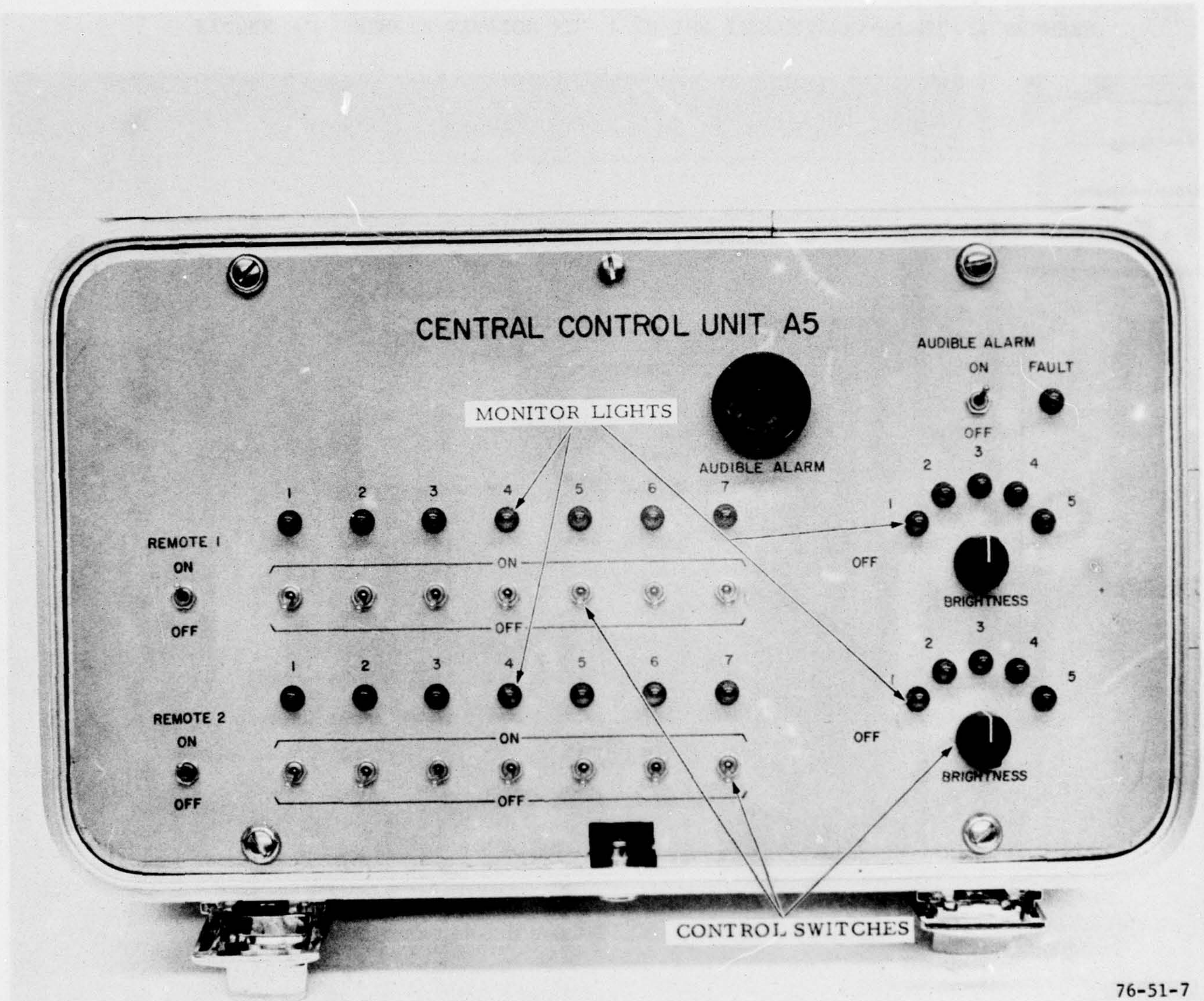

FIGURE 7. DISPLAY AND CONTROL PANEL

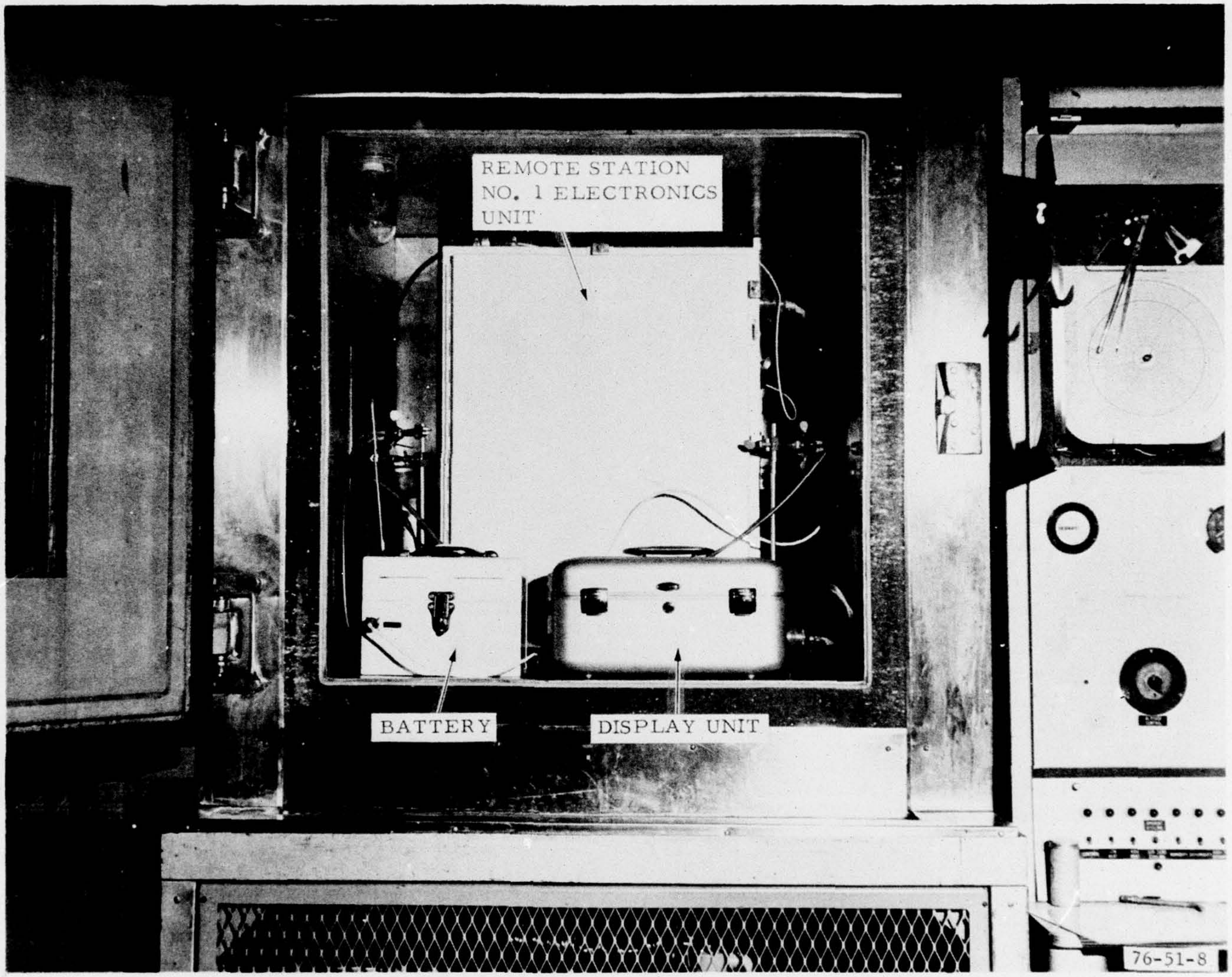

FIGURE 8. REMOTE STATION NO. 1 IN THE TEMPERATURE-HUMIDITY CHAMBER